2011

Growing Biomass Fuel Industry, Declining Local Forage Demands, and Changing Greenhouse Gas Emissions from US Agriculture: A Case Study

Paul W. Gallagher
Iowa State University, paulg@iastate.edu

Jeremiah Richey
Iowa State University

Growing Biomass Fuel Industry, Declining Local Forage Demands, and Changing Greenhouse Gas Emissions from US Agriculture: A Case Study

Paul W. Gallagher[1,*], Jeremiah Richey[2]

[1] Iowa State University,Ames, Iowa/USA
[2] Iowa State University, Ames,Iowa/USA
* Corresponding author. Tel:010-515 294 6181, Fax: 010-515-294-0221, E-mail:paulg@iastate.edu

Abstract: This paper investigates the effect of a biomass crop introduction in a local market where field crops, cattle forage and biomass crops compete for the agricultural resources and determine land use. A simulation study for a State in the US (Minnesota) with extensive and diverse agricultural resources that could also support a biomass industry is reported. Local market impact on prices and land use is summarized. A local biofuel industry with 1.0 billion gallon capacity can transform declining local land values to stable or moderately increasing land values, partly because secular declines in cattle forage can be replaced with biofuel demands. The effects of greenhouse gas emissions and sinks are also estimated. The local agriculture sectors' net greenhouse gas changes are converted from a net emission to a net sink position with a biofuels industry-we calculate an annual net improvement of 55 bil. Lbs CO_2 –equivalent, due, in part, declining cattle emissions and favorable land use effects from expanding hay production.

Keywords: *Land rent, Land Use, livestock emissions, Switchgrass, Greenhouse gas(GHG).*

In the US, Biomass fuel technology broadens the potential agricultural resource base to include marginal land that is not suitable for corn production. There are some concerns about increasing greenhouse gas emissions when a land conversion process accompanies a biomass processing expansion [1]. H owever, existing analyses do not account for the market environment and dynamic adjustments already occurring in local agricultural resource markets. This paper accounts for the local competition between biomass feedstock and cattle forage, the land conversion that would accompany an unrestricted biomass fuel expansion, and the cattle industry decline that is already occurring in potential biomass supply areas of the United States. Since the relevant markets are local, we report a case study of a *representative* State (Minnesota) in the United States that has extensive and diverse agricultural resources that could adapt to biomass crops.

The first section reports an econometric estimation of the profit and dynamic factors influencing cattle population. The second section summarizes a model of the local forage market that presently defines the use of low grade agricultural land. The third section reviews CO_2 accounting procedures, specifically explaining how market changes influence emissions from crops, livestock, and pasture land. E stimates of changes in equilibrium soil carbon levels are also provided. The fourth section presents some 10 year projections of economic variables and global warming indicators. A well-known baseline for US agriculture is the reference for the global commodity markets that define resource market outcomes, and global warming indicators. Then local market outcomes and global warming indicators are given for the case where an expanding biomass fuel industry uses some of the local resources in the given market environment.

1. Market Environment

This section is an overview of the simulation model. There are three main elements in the market model. First, a land use model defines the amount of land used for crops, pasture, and left idle. S econd, new estimates of the factors determining local cattle populations are presented. Third a model that incorporates the competition among supply of the three main forage types(hay, pasture and stover) is discussed. *Additional documentation, such as the* *land use model, Worksheets for greenhouse gas emissions and sinks, and the local forage baseline are available at www2.econ.iastate.edu/faculty/gallagher*

1.1. Land Use.

Land demand is determined in local agricultural land rental markets. We use an updated version of a recent land use model [2]. Revised estimates land use data from the 2007 census of agriculture, and include land demands for each major crop (corn, soybeans, wheat, cotton, and hay).

1.2. Cattle Population Adjustment

Minnesota's cattle population adjustment is typical of the states in the eastern half of the US. That is, there has been a steady decline mixed with episodes of cyclical adjustment. The decline is likely due to contracting US beef consumption and squeezing marginal producers. Cyclical adjustments likely occur in response to changing market conditions. Beef and Dairy cattle response estimations for Minnesota suggests population slowly adjusts to past profits, populations and also exhibits a secular decline. Our results were estimated using data from the 1969 to 2009 period:

$$\begin{array}{llllll} Nb_t = 0.741 + & 0.118\pi b_t + & 0.952 Nb_{t-1} - & 0.191 Nb_{t-2} + & 0.118\ln(T) & \\ (2.3) & (1.8) & (6.0) & (1.1) & (1.8) & (1) \\ adj - R^2 = 0.96 & & DW = 1.9 & & s = 0.103 & \end{array}$$

$$\begin{array}{lllll} Nm_t = 0.105 + & 0.710\pi b_t + & 0.710 Nb_{t-1} & 0.021\ln(T) & \\ (1.5) & (2.2) & (2.2) & (2.2) & (2) \\ adj - R^2 = 0.97 & & DW = 2.5 & s = 0.037 & \end{array}$$

where k=b for beef, d for dairy

Nk_t is the cattle population in year t, in million head;

πk_t is the profit margin, in \$/lb output

T=1 before 1976, 2 in 1976,3 in 1977,…,

1.3. Forage Substitution Model

We assumed that forage demand is a fixed proportion of the cattle population. Then substitution among the three main forage inputs (hay, pasture, and corn stover) is described with a constant elasticity of substitution demand function. The demand equation satisfies baseline market shares of hay, pasture, and stover. It also has an elasticity of substitution of 3.0.

A 2009 baseline for forage consumption and market shares of hay, pasture, and stover was deduced available information. Total forage demands were developed from recommended rations and averages were constructed across a typical age and sex distribution. Pasture consumption of forage was approximated from baseline cattle populations, grazing season length and daily forage requirements. Hay consumption is approximated by hay production. Finally, stover demand is the difference between total forage demand versus hay and pasture demand.

2. Measuring Global Warming Sinks and Emissions

Existing procedures for measuring CO_2 equivalent emissions were restated as functions of appropriate economic variable instead of numbers calculated on baseline levels, in order to account for the effect of changes in economic variables. G enerally, emissions functions depend on production, area, and livestock populations. All relationships are proportional. All measurements are expressed in a common CO_2-equivalent basis.

The GREET model of agricultural emissions is used for corn and soybeans. But revisions for recent fertilizer and energy use data were included [3]. Similarly, GREET fertilizer and fuel emissions coefficients were combined with appropriate fertilizer and fuel data for wheat, hay and switch grass.

IPCC Tier I procedures for beef and dairy cattle were used to estimate livestock based emissions [4]. Enteric and Manure emission of dairy and beef cattle in North America are included. Also, the N2O equivalent emissions from spreading livestock manure on land are included with livestock instead of land, because this activity is economically linked to the livestock population.

Estimates of the equilibrium soil carbon stock are also provided. Here we use the IPCC teir I procedure, which identifies a reference level for soil carbon in undisturbed soil, and a set of multipliers for several different categories of land use [5]. The reference carbon level and multipliers for the land use categories in our model are shown below:.

Table 1.multipliers for soil carbon, by land type

IPCC Classification (Table #)	Native-C multiplier (0/1)	Model's land use variable (symbol)
Native (5-11)	1.00	Other farmland (Lg-Gs)
Unimproved Grassland (5-10)	0.77	Pasture Supply (Gs)
Idle cropland (5-12)	0.70	Cropland in pasture (Cdg)
Set Aside<20 yr (5-12)	0.80	CRP land (Cdz)
Cropland in Crops (5-12)	0.70	Corn, Soybeans, Wheat (Cdc,Cds,Cdw)
Improved pasture, Hay (5-10)	1.10	Hay (Cdh)
Improved pasture, Hay (5-10)	1.0	Switchgrass (Cdsg), conservative

Native C-stock: 80 mt / ha (130.87 ton CO_2 / acre)

It is important that minimal carbon release is possible when converting land from pasture to hay or biomass crops. Indeed, switch grass is already used as forage in managed pasture [6]. Further, no-till planting methods for switch grass on pasture appear to have a minimal environmental effect [7].

Three main aspects of Carbon are summarized in simulations. First, the CO_2 sink associated with the switch grass crop is an initial approximation for the fossil fuel replacing benefit of biofuel. Second, the change in livestock emissions, a decline, represents a potential offset for adverse lanc-conversion emissions associated with starting a bio fuel industry. Third, the change in soil carbon stocks (expressed as CO_2-equivalent) is calculated as the difference between annual estimates of equilibrium soil carbon stocks. Also, the net sink of other crops (corn, soybeans, wheat, and hay) is also calculated, even though much of this sink likely belongs to an out-of-state carbon budget for corn-ethanol, consumption in other states, or use in a foreign country. It is helpful to see how field crop CO_2 sinks change with changes in switchgrass sinks, livestock emissions, or soil carbon capture/release.

3. Baseline

The most recent USDA 10 year baseline defines reference levels for the main commodity prices that drive (are exogenous to) the local biomass supply/forage demand model [8]. However, the reference prices for corn, soybeans, wheat, beef, and milk are adjusted to reflect a distortion-free policy environment that would put a new biomass industry on equal footing with other established industries.

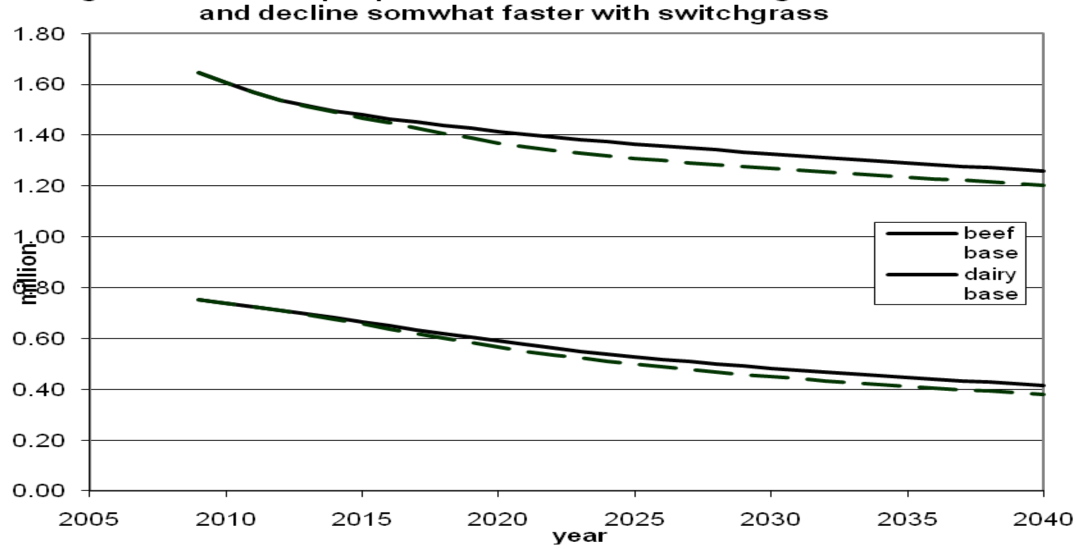
First, the corn-ethanol industry has over-expanded as a result of a mandate for minimum ethanol use, called the Renewable Fuel Standard (RFS). About 4.0 billion gallons per year (BGY) of the RFS extends beyond supply increases that can be gathered from corn yield growth on land that is presently used. The price-effects of one-half of the overexpansion, or 2.0 BGY, is subtracted from the baseline corn and soybean prices using multipliers developed elsewhere [9]. Hence some overexpansion effects, which result in artificially high prices for substitute commodities and land rent, are removed from the baseline.

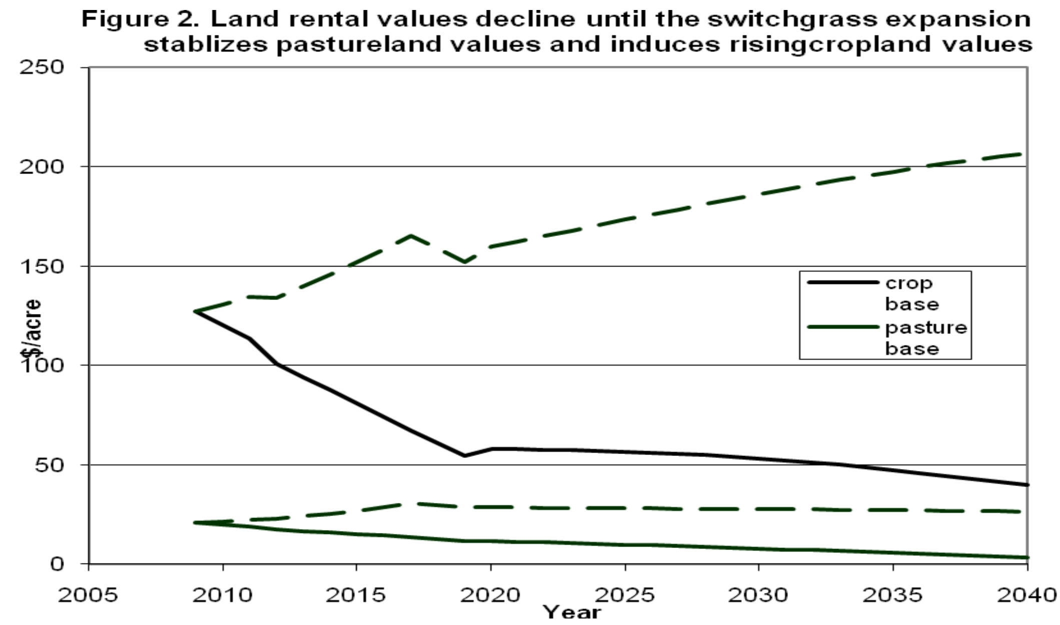
Second, a 30% import duty on US Beef imports [10] artificially holds US beef prices above market levels, encourages overproduction, and inflates local forage demands and prices for marginal land. For a first approximation, USDA baseline prices for beef are reduced by 30%. Milk prices are also reduced by 30%, because domestic milk prices are supported by an elaborate quota system.

Other exogenous assumptions for the projection period also fit today's apparent circumstances. For instance, cropland declines at 0.7 million acres (3.1%) per decade, as defined by the most recent census of agriculture. But other(non-cropland)farmland remains constant at about 5.0 million acres. Hay yields remain constant at at the average of recent values- the experience of the last two decades. Corn yields increase 20% over the first few years of the projections, and then remain level. Finally, a zero inflation rate for the CPI reflects today's depressed macro-economy.

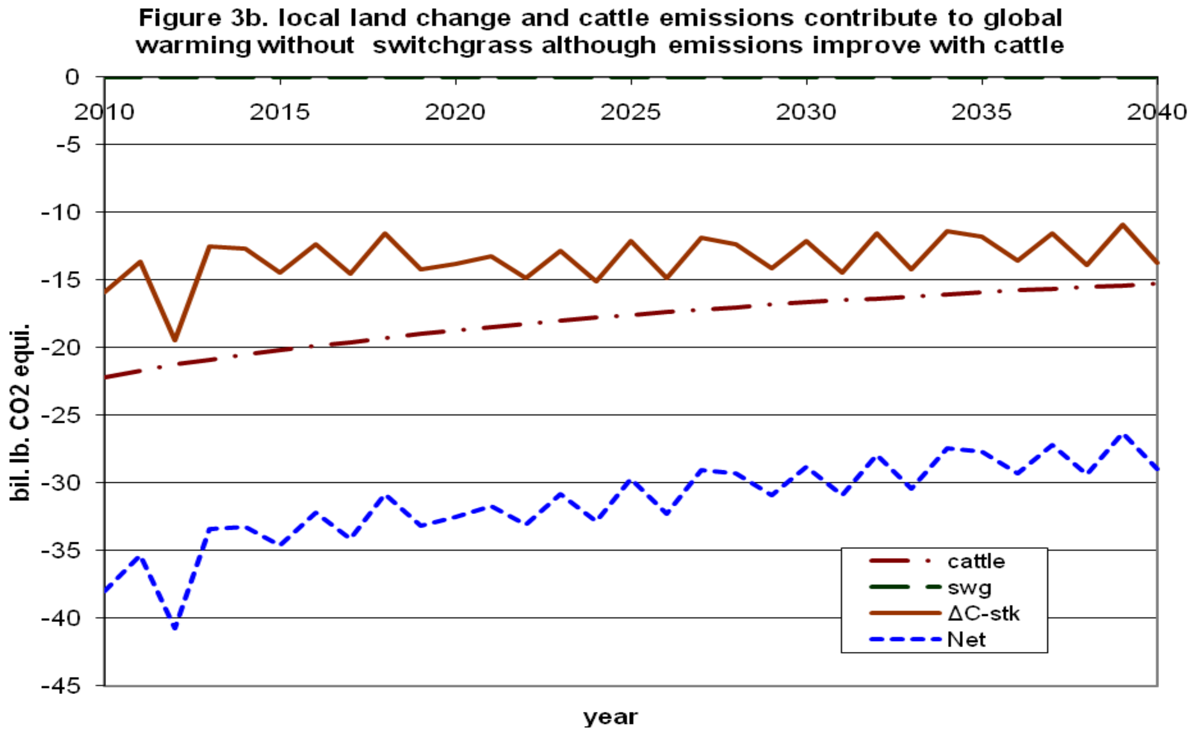
The hypothetical baseline defines a scenario of declining commodity prices, cattle populations (figure 1), and local land prices (figure 2). Consequently, the demands for local resources are also declining. The prices of grains that are internationally traded would also gradually decline. Thus, the demand for local land resources and land rental rates are also declining.

Figure 1. The catle pouplation will continue declining in the future and decline somwhat faster with switchgrass





Emissions for two of our three main activities are reinforcing, and produce net CO_2 emissions under baseline conditions. Cattle emissions are substantial, but declining. In 2009, emissions are 22.6 bi l. lbs CO_2-equivalent, but decline to 15.2 bi l. lbs at the end of the simulation period. Equilibrium Carbon stocks decrease steadily at a rate of about 12.0 bi l. lbs CO_2, annually, throughout the 30 year simulation period (figure 3b).



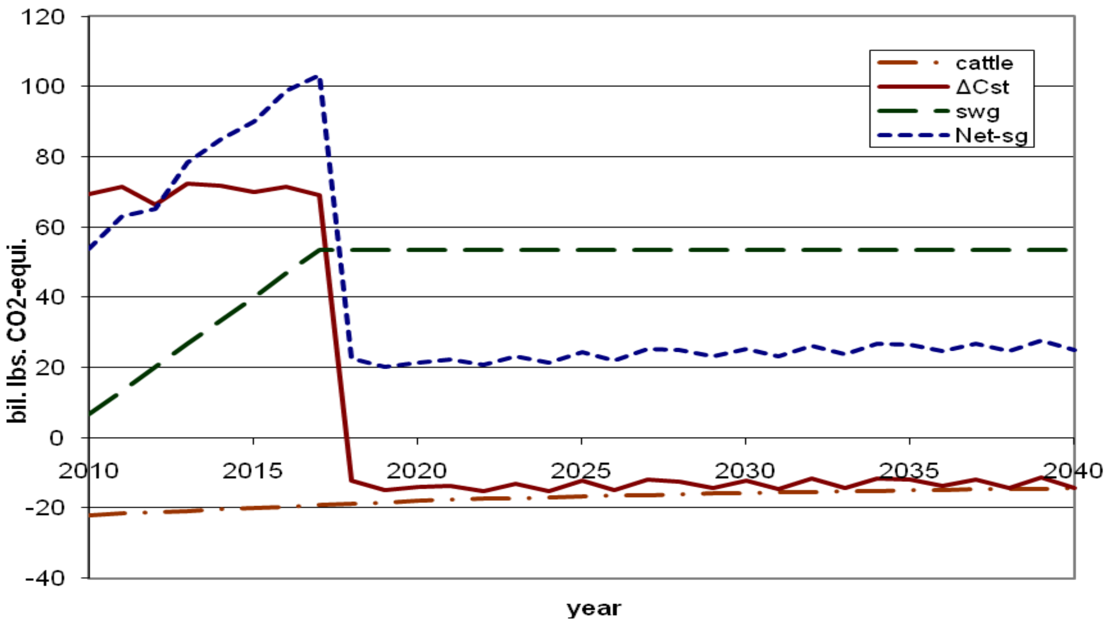
4. Biomass Fuel expansion

Here, an exogenous land demand expansion for a biomass crop (switchgrass) gradually increases the total area used for biomass to 4.0 million acres over a 5 year period that begins in 2010 (the first year of the simulation). The 4.0 million acre area is split equally between cropland and pastureland. Switchgrass is only one of several potential biomass crops, but still has a representative crop yield and carbon sink/emission profile.

The gradually expanding land demands restore increasing land prices (figure 2). But the increases are moderate; cropland rentals take three decades to double; pasture rental rates increase by about 20% over the first ten years, and remain stable thereafter.

The Greenhouse gas profile would also improve (figure 3s). First, increasing switchgrass production implies a substantial net carbon sink, most of which replace fossil fuels. Second, livestock emissions continue to improve through cattle reductions, accounting for about 20% of switchgrass emissions. Third, the equilibrium carbon stock would increase substantially during the biomass crop expansion phase, mainly because of the carbon storage profile of switchgrass. But the annual increment to the equilibrium carbon stockreverts to an emission thereafter. Nonetheless, three main activities combine for a net carbon sink (figure 3s).

Figure 3s. GHG sink from growing biomass fuel adds to a beneficial land use sink and offsets cattle emissions.



5. Conclusions

This study looks at the introduction of biomass fuel in local agricultural markets where land use and forage demand are defined. The hypothetical biomass expansion was split between cropland and pastureland, even though land costs per unit of biomass appear lower using marginal land.

The reference point is a distortion-free baseline created by removing recent over-expansion in corn ethanol and protection for livestock products. The baseline is characterized by declining land use values for cropland and pasture land.

The substantial biomass expansion is enough to support a 1.0 billion gallon ethanol industry. And the expansion merely restores stable or moderately increasing land values. Hence, The local agricultural resource is large enough to accommodate biomass ethanol production at a large scale.

The expansion on marginal land has mainly a local market impact. About 40% of the marginal land comes from the secular decline in cattle population and overall forage needs.

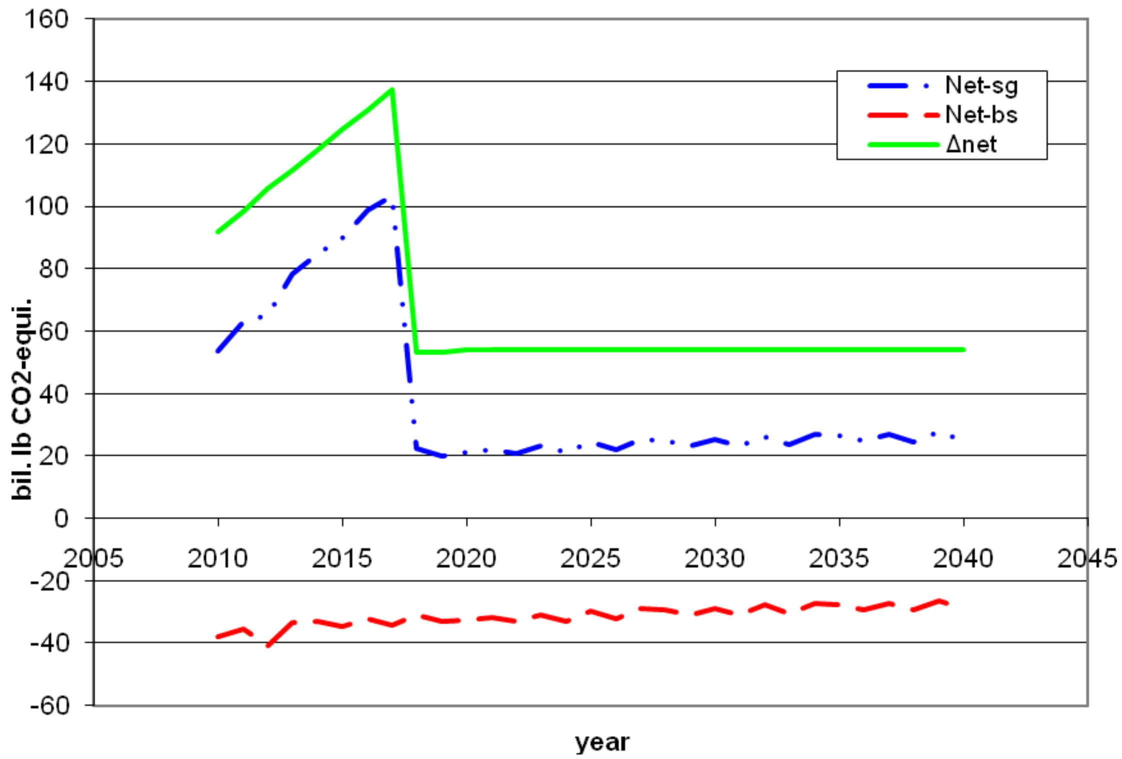
Otherwise, cattle rations shift away from pasture and towards hay and corn stover. In fact, hay demand grows despite declining cattle populations in the biofuel scenario. Compared to the baseline, the switch grass expansion restores stability to pasture rental rates.

The CO2 accounting focuses on changes in local agriculture as well. First, the direct benefit for switchgrass used as biofuel is included. Second, declining cattle emissions are also included. Third, the land use change effects on equilibrium soil carbon storage are included. Results suggest an increase in soil carbon storage, especially during the switchgrass expansion phase. Increasing hay production likely contributed to improving carbon storage as well. The change in net greenhouse gas sinks from the three local sources is 60 bill lbs CO2 equivalent, annually, after switchgrass production is established. The change in net sinks exceeds 100 bill. Lbs during the switchgrass expansion phase.

Two tasks remain for a comprehensive CO2 accounting. First, several other states with similar agricultural resources that are potential biomass supply areas should be incorporated into the analysis. Second, the totality of local changes must be considered in national and international markets. It seems plausible that the cattle decline would be absorbed into a declining demand for beef. However, the corn land expansion induced by the cropland expansion for switchgrass already appears large relative to the corn ethanol shift used to produce a distortion-free baseline. Accordingly, further simulations might usefully focus exclusively on expansions on marginal land.

The moderate price impact, beneficial lifecycle analysis, and potentially local impact for the marginal land expansion merits further attention. EPA regulations that restrict changes in use of permanent pasture may also deserve further scrutiny.

Figure 4. moderate net GHG sink with biomass replaces a net GHG emission without biomass for a large improvement.



References

[1] J. Fargione, J. Hill, D. Tilman, S. Polasky, P. Hawthorne, Land Clearing and the Biofuel Carbon Debt, Science, Vol 319, 29 February 2008, p.1235-1238.

[2] P. Gallagher, P. and H. Shapouri, Biomass Crop and Ethanol Supply from Agricultural Lands in the United States, AER No. 844, U.S.. Dept. of Agriculture, Nov. 2008.

[3] M. Wang, Y.Wu, and A. Elgowainy, The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model,' Operating Manual for GREET: Version 1.7, Center for Transportation Research, Argonne National Laboratory, http://www.transportation.anl.gov/software/ Greet/index.html, February 2007.

[4] Intergovernmental Panel on Climate Change. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Reference Manual (Volume 3) Agriculture, 1997. http://www.ipcc-nggip.iges.or.jp/public/gl/invs6c.html

[5] Intergovernmental Panel on Climate Change. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Reference Manual (Volume 3) Land Use Change and Forestry,1997.

[6] J C Henning, Big Bluestem, Indiangrass and Switchgrass, University of Missouri Extension G4673 October 1993,

[7] KJ Goddard and JWalton, Switchgrass for Biofuels University of Tennessee Biofuels Initiative, October 10, 2007.

[8] Interagency Agricultural Projections Committee, USDA Agricultural Projections to 2019, Long-term porojections report OCE-2010-1, February 2010.

[9] PW Gallagher, Corn Ethanol Growth in the US without Adverse Foreign Land Use Change: Defining Limits and Devising Policies, Biofuels, Bioproducts, and Biorefining, May/June 2010.

[10] PW Gallagher, A look at US-Brazil ethanol trade and policy, Biofuels, Bioproducts, and Biorefining, September 2007.